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# Screening movement dysfunctions using the overhead squat

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## OVERVIEW

The aim of this article is to provide a rationale for using the overhead squat as a key method for screening movement quality. The authors will identify key flaws in interpreting movement quality during this pattern without guidance of 'what to look for'. Consequently, the authors have suggested the use of a simple grading system (guided by existing recommendations), thus allowing coaches to monitor overhead squat performance more accurately.

## Introduction

Movement screening has been a highly debated topic for strength and conditioning (S&C) coaches in recent years. Numerous methods exist for assessing movement quality, ranging from Gray Cook's Functional Movement Screen (FMS)<sup>4,7,8,11</sup> and the Movement Competency Screen (MCS),<sup>17,18</sup> adopted by many in high performance sport in New Zealand to the overhead/single leg squat: they are suggested as useful indicators of movement quality by the National Academy of Sports Medicine (NASM).<sup>9,10</sup> The common denominator for these screening methods is that they all employ the overhead squat as one of the key assessments for an indication of gross movement quality. The FMS provides a score ranging from 0-3 (3 = performed with perfect form, 2 = performed with compensation, 1 = performed poorly and 0 = unable to perform the assessment due to pain),<sup>4</sup> whereas the NASM prefer to focus on what movement compensation occurs at each joint with possible over- and under-active muscles that

could be contributing to the dysfunction. Ultimately, NASM's method delves into the possible reasons for such compensations in much greater detail than the FMS.

However, there are advantages to a numerical grading system such as that of the FMS. Having a score at the end of the assessment process allows for easy comparisons to be made during times of re-assessment. In addition, a numerical score can allow practitioners to run data analysis on the quality of movement to compare it to other aspects of an athlete's physical development. This line of research has been done by those investigating the relationship between the FMS and athletic performance,<sup>7,12,21,22</sup> and although the relationship between the two appears to be very limited, the methods employed in these studies have primarily used the sum score of the seven FMS assessments, as opposed to looking at each score individually.

The practicality of using an exercise such as the overhead squat would appear to be quite strong, as it challenges the mobility

of all key joints in the kinetic chain through a movement pattern so commonly used in S&C practice. There is also the time efficiency benefit of using just one screening exercise in comparison to the FMS' seven. Although the literature has not focused on this particularly, the notion of 'saving time' is always an important reality in the field and a thorough FMS protocol is likely to take around 10 minutes per athlete. Considering a high number of coaches work in a team sport environment, the time it takes to run the FMS on a large squad may outweigh any potential benefits that it may have to offer.

### Why use the overhead squat?

Research looking at the overhead squat would appear to be growing in recent years. Atkins et al.<sup>2</sup> investigated the presence of bilateral imbalance in 105 elite youth soccer players ranging from U13-U17 level. The bodyweight overhead squat (as per the FMS protocol) was conducted on a twin force plate system as part of a pre-season screening process so that peak ground reaction force (PGRF) could be analysed for both limbs (see Table 1).

Table 1 portrays a significant difference in force between left and right limbs for each individual age group tested. In addition, the reported asymmetry scores correspond only to the age group that they fall under in the table. Although not specified in Atkins'

paper, the asymmetry percentages were most likely calculated using the equation proposed by Impellizzeri et al.<sup>16</sup> If the PGRF values are input into the equation below, the reported percentages are observed. There are other equations that can calculate asymmetries, but none that produce the above results. Therefore, although speculative, it is likely that by default this was the method used:

$$\text{Bilateral imbalance (\%)} = (\text{stronger limb} - \text{weaker limb}) / \text{stronger limb} \times 100$$

It is encouraging to see a large sample size being used within an elite environment, thus allowing comparable data across a spectrum of age groups. The key reason for the imbalances were not completely clear, although it was hypothesised that maturation may have been responsible for the higher percentage differences at the ages of 13-14.<sup>2</sup> Interestingly, the higher scores in PGRF between limbs were noted on the non-dominant side in each age group, a concept most likely related to the notion of 'limb symmetry'. A common misconception is that if one limb is stronger than the other, it does 'more work', when in actual fact it most likely does less. With muscular contractions being dictated by the central nervous system, a stronger limb does not need to innervate as many muscle fibres in a bilateral exercise in comparison to the weaker side, thus the stronger limb most likely does 'less work', not more.<sup>15</sup>

**Table 1. Differences in PGRF between left and right limbs for each age group classification (adapted from Atkins et al 2013)**

	U13 (n = 18)	U14 (n = 17)	U15 (n = 18)	U16 (n = 21)	U17 (n = 18)
<b>PGRF (right)</b>	381 ± 104	376 ± 89	468 ± 126	464 ± 93	485 ± 54
<b>PGRF (left)</b>	407 ± 129	431 ± 85	528 ± 109	511 ± 103	507 ± 83
<b>% Difference</b>	6	13	11	9	4

NB<sup>1</sup>: All percentage differences significant at  $p \leq 0.01$

NB<sup>2</sup>: All Peak Ground Reaction Force (PGRF) values are reported in Newtons

**Table 2. Mean values for peak joint angles and peak joint moments during the overhead squat (adapted from Butler et al, 2010)**

VARIABLE	SCORE OF 1	SCORE OF 2	SCORE OF 3	P
Peak dorsiflexion (°)	24.5 ± 2.3	27.9 ± 2.6	31.4 ± 1.8	0.10
Peak plantarflexion moment (N/kg)	-0.27 ± 0.03	-0.25 ± 0.02	-0.21 ± 0.02	0.15
Peak knee flexion (°)	84.7 ± 4.3	111.0 ± 4.9	130.7 ± 3.8	< 0.01
Peak knee extension moment (N/kg)	0.45 ± 0.04	0.56 ± 0.05	0.63 ± 0.03	< 0.01
Peak hip flexion (°)	88.8 ± 5.1	117.5 ± 4.0	121.1 ± 2.0	< 0.01
Peak hip extension moment (N/kg)	-0.36 ± 0.07	-0.56 ± 0.05	-0.55 ± 0.04	0.34

## 'Having a score at the end of the assessment process allows for easy comparisons to be made during times of re-assessment'

Although it was not reported what these differences 'looked like' to the coach's eye (as with many subjective screening methods), Atkins provides evidence that significant differences do exist between limbs in a controlled, bodyweight condition. Furthermore, the idea of obtaining movement symmetry is warranted when viewing the overhead squat because this is one of the aspects coaches typically look for during screening assessments.<sup>9,10</sup>

### Flaws in grading systems

Butler et al<sup>6</sup> undertook a biomechanical analysis of the overhead squat assessment in 28 subjects who were assessed on their performance via the FMS grading criteria, meaning each participant was graded 1-3 dependent on their form during the test. Ten subjects scored perfectly on the test (score of 3) with nine each being graded as a '2' or '1' respectively. Peak joint angles and peak joint moments were measured using 3-D motion analysis: the results can be seen in Table 2 (on page 23).

When interpreting the results from Butler's study, there was no significant difference between ankle range of motion, whether subjects performed the test perfectly (score of 3) or with major compensations (score of 1 or 2). However, as technique improved, there was a significant difference in the amount of knee and hip flexion reached at the bottom of the squat between each group. If ankle dorsiflexion was not significantly different between groups, but hip and knee flexion was different, then this would indicate that subjects adopted more of a 'hip hinge' strategy to increase their depth in the squat pattern, a notion that has been reported to fall in line with optimal squatting technique.<sup>20</sup>

However, it must be remembered that any grading of the overhead squat in line with the FMS protocols, (as per this study), is at the discretion of the coach's interpretation of optimal technique. This may prove problematic for such a compound movement pattern because multiple joint movements will contribute to the performance of the task. Furthermore, common unwanted compensations seen in the overhead squat such as knee valgus, excessive forward lean or arms falling forward<sup>9,10</sup> were not investigated because the FMS criteria does not identify these issues in the immediate grading of the screen other than as a reflection of a lower score. The demanding nature of performing an 'optimal' overhead

squat means that a more complex system may be required than that which the FMS offers. Therefore, specific grading criteria that encourage practitioners to look for common unwanted patterns may help to provide a more accurate interpretation of this movement as a screen.

This line of thought is supported in new research from Whiteside et al,<sup>23</sup> who compared 'real-time' grading of the FMS tests on 11 female collegiate athletes from a certified FMS rater versus objective methods of a motion capture system. Specific kinematic information was constructed for the motion capture condition to align itself with anticipated optimal technique for each of the tests. As an example, during the overhead squat, the motion capture system quantified whether there was any lumbar flexion present by determining if there was a L5-S1 joint flexion angle of  $<5^\circ$ . For depth of the squat, the long axis of the femur was required to align itself parallel with the axis of the transverse plane (which would have been identified from the motion analysis software).<sup>23</sup> Results indicated only an 18.2% level of agreement between the two methods when assessing movement quality in this test. The authors noted that during complex movement patterns, raters are required to survey multiple areas in a small number of repetitions, and thus the potential to miss vital kinematic information is greater in real-time.

To understand this further, during one of the subject's assessments, his left femur descended below parallel during the test, but his right did not, which means that the score provided by a rater in real-time is dependent on where they are positioned. Furthermore, an additional seven of the subjects were within  $5^\circ$  of the parallel criteria and given that real-time visual kinematic estimates have been shown to demonstrate errors of between  $10-15^\circ$ ,<sup>3</sup> it is unlikely that this distinction is fully possible with the naked eye. Once again, a grading system that specifically encourages coaches to identify more detailed, unwanted movement mechanics may reduce the margin of error when attempting to obtain an accurate impression of movement quality during the overhead squat.

Specific kinematic differences have also been seen between genders. Mauntel et al<sup>19</sup> examined sex differences between 30 males and 30 females during the overhead squat assessment and used an electromagnetic motion tracking system to quantify lower body joint kinematics. Knee flexion, valgus

and internal rotation, hip flexion, adduction and internal rotation, and trunk flexion and lateral flexion were all measured. Males exhibited significantly greater knee valgus ( $p = 0.004$ ) and hip flexion ( $p = 0.003$ ), compared to females with no other significant differences reported between the two groups.<sup>19</sup> The mean difference in hip flexion was  $\sim 12^\circ$  which, in addition to being statistically significant, may also be visible with the 'coach's eye', suggesting that the depth of the movement may provide more obvious differences when comparing between genders. However, coaches should not assume that this will be the case for all male/female comparisons; instead, they should treat each set of screening results as their own case. Consequently, should any confusion arise when assessing differences between genders or otherwise, a grading system would further refine what coaches are looking for when interpreting results.

Finally, Aspe and Swinton<sup>1</sup> investigated differences in muscle activation during three repetitions between the back squat and overhead squat at 60, 75 and 90% 3RM in 14 elite male rugby union players. Electromyography activity for the rectus abdominis, external oblique and erector spinae were recorded for the trunk musculature. The overhead squat produced significantly greater activity in the anterior abdominal muscles (2-7%) under all three loads, but only in the eccentric phase of the lift. In comparison, the erector spinae activated significantly more in the back squat condition, this time in the concentric phase of the lift under all three conditions.<sup>1</sup> Although under moderate to heavy loads, it is interesting to note that the overhead squat was able to encourage higher abdominal activation (at least in one phase of the lift).

It has been previously acknowledged that full flexion of the shoulder joint during the overhead squat pattern will challenge the extensibility of the latissimus dorsi (LD) muscle.<sup>5</sup> Bilaterally, the LD can extend the lumbar spine (due to its attachment on the pelvis), if it lacks optimal range of motion and it is plausible that the abdominal complex has to work harder during an overhead squat to maintain a stable lumbo-pelvic-hip complex, in an attempt to keep the pelvis neutral.<sup>5</sup> The caveat to this thought process is that a bodyweight condition was not part of the methodology in Aspe's research and neither was LD/shoulder flexion range of motion tested; therefore, whether these results are only applicable under load requires further

investigation. However, the principle of these findings is that an overhead squat may identify potential issues around the trunk, which may otherwise be missed with 'non-overhead' squat screening.<sup>5</sup>

### Recommendations

In conclusion, the research demonstrates a number of areas where the overhead squat may be considered as a method for screening movement quality. Notable differences in GRFs,<sup>2</sup> joint positions,<sup>6</sup> kinematic interpretation,<sup>19,23</sup> gender differences<sup>19</sup> and muscle activation,<sup>1</sup> have been depicted, suggesting that multiple considerations do exist for this one exercise. However, from a practical perspective, not all practitioners will have access to expensive force plates, motion analysis systems or electromyography (EMG), and thus an in-depth laboratory-based analysis of the overhead squat is not always viable.

Furthermore, existing methods such as the FMS do not appear to take into consideration the complex nature of the overhead squat and all the typical dysfunctions that may be associated with it.<sup>23</sup> Therefore, having a deeper understanding of common compensations may assist the coach when attempting to assess this pattern accurately. It should also be noted that although complex 3-D motion analysis may not be viable for all coaches, video analysis from smart phones/tablets is most likely a tool worth considering. This will speed up the screening process in real-time, although accurate analysis of the movement will most likely be enhanced if graded later.

Whether graded in real-time or assessed afterwards, it is up to the practitioner to ensure that they understand what each compensation looks like in order to grade the movement accordingly. Retaining the detail of how the major areas in the kinetic chain (feet, knees, lumbo-pelvic-hip complex, shoulder and head) are viewed as per the NASM's suggestions, while incorporating some kind of scoring system (as the FMS does), may allow practitioners to monitor progress in such a compound screening pattern more easily, by comparing scores of an athlete's movement competency over time. In addition, having a score for each side of the body during a bilateral pattern may allow coaches to investigate further this movement's relationship with any other unilateral screens or tests undertaken. Finally, comparison scores of movement quality between left and right sides may

**'Under moderate to heavy loads, it is interesting to note that the overhead squat was able to encourage higher abdominal activation'**

**Table 3. Proposed grading criteria for the overhead squat assessment (guided by suggestions from the NASM)<sup>9,10</sup>**

JOINT	COMPENSATION	LEFT	RIGHT	NOTES
Foot/ankle	External rotation	○	○	
	Feet flatten	○	○	
	Heel raise	○	○	
Knee	Valgus	○	○	
	Varus	○	○	
LPHC	Forward lean		○	
	Lumbar arching		○	
	Lumbar rounding		○	
Shoulder	Arms fall forward	○	○	
	Elbows flex	○	○	
Head	Protruding		○	
<b>Score: Left/Right</b>				
<b>Total score:</b>				

provide coaches with a useful impression regarding limb symmetry during this screen, a concept that does not always spring to mind when we prescribe/assess bilateral exercises.

Although the FMS has previously been subject to correlational studies,<sup>7,21,22</sup> and shown little association with performance or injury prediction, methods have used the sum score of the seven FMS tests as opposed to making any comparisons with individual tests. Therefore, guided by existing suggestions from the NASM, we suggest that coaches ask athletes to perform five repetitions which are viewed from an anterior, lateral and posterior viewpoint using the criteria in Table 3 – if and when the overhead squat is used for grading an athlete's movement in the field.

Ultimately, the goal when using this criterion for assessing movement quality during the overhead squat is to score zero. Table 3 has only identified compensations to an athlete's movement, and therefore any 'ticks' would be a result of reduced movement efficiency for this task. The parts of the kinetic chain which do not require a left/right distinction (LPHC and head) simply require an acknowledgement of any unwanted compensation in the same way.

When interpreting scores from the grading system – although any score can be used in conjunction with other data analysis methods – the main goal is to address the compensation in question and not rely on any 'relationships' that may exist. In

addition, for the checkpoints that are graded on both sides of the body, the total score should count both left and right 'ticks' (should the compensation occur on both). This means that the highest number achievable (which would be considered the worst score) is 18, whereas a comparison of left/right scores is out of 7. To reiterate, the emphasis should always be to address each unwanted movement accordingly and specific strategies on how best to do this would be at the discretion of the coach. Naturally, no normative data exists for this grading system at present; however, it is of course in the interest of athletes to exhibit none of the aforementioned patterns described above. Lastly, in order to understand the context of the proposed grading criteria, it is necessary to identify the position that coaches should instruct athletes to adopt for the assessment (see Table 4).

### A range of squat positions

Finally, in order for coaches to characterise the compensations that may be seen in Table 3, a range of pictures have been included, and can be seen on the following pages, so that coaches can determine whether these compensations are present during the screening process.

### Conclusion

To summarise, the existing research would seem to indicate that existing imbalances



**Table 4. Instructions for the S&C coach to give to the athlete for the overhead squat assessment**

INSTRUCTION	RATIONALE FOR INSTRUCTION
Set feet hip width apart at 12 o'clock	Narrow foot position, set straight ahead will require optimal levels of dorsiflexion [20-30°] <sup>10</sup> to avoid compensations at the foot/ankle complex. It should be noted that this may not be considered optimal foot positioning for loaded squat training; it is designed to provide an impression of ankle mobility during the movement
Shoulders in full flexion	Optimal shoulder flexion has been reported to be 180° <sup>10,14</sup> and coaches should instruct athletes to 'raise their arms above their head' and maintain this position throughout the screen. Coaches are looking to see if the arms are a continuation of straight spinal alignment throughout the available range of motion
Keep head neutral/ eyes looking forward	It has been suggested that this falls in line with optimal squatting technique. <sup>20</sup> If the athlete is allowed to flex at the neck (look down), this may make it harder to visually distinguish compensations at the shoulder joint, such as the arms falling forward
Ask athlete to remove footwear	In order to standardise testing procedures, all athletes should remove footwear so that no 'assistance' can be provided for any reduced ankle mobility
Ask athlete to squat as deep as possible	This should encourage athletes to challenge their depth in the squat pattern. Some compensations, such as knee valgus and excessive forward lean, may not be apparent at shallow depths; it is therefore in the interest of the coach to determine if full range of motion is available and whether the athlete has the strength to maintain form throughout the available range. Furthermore, visual demonstrations have been suggested as a more advantageous strategy to enhance motor learning; <sup>13</sup> the authors suggest that no demonstrations are provided as this may affect outcomes.

may be present during the overhead squat in a range of athlete and non-athlete populations. A number of research studies are still employing the methods advocated by the FMS (for the overhead squat), but it is plausible that these guidelines may be lacking some accuracy, in addition to being quite time-consuming if practitioners choose to use all seven tests. Expensive laboratory-based methods have highlighted flaws in subjective screening protocols, but may not be practical for coaches in the field. Therefore, a grading system that goes into more depth regarding unwanted movement compensations for the overhead squat (which appears to be so commonly used in practice) may enhance its accuracy as a method of assessing movement quality. The

proposed grading criteria (as supported by the NASM), may assist coaches when aiming to identify kinematic asymmetries during this movement pattern and make it easier to monitor progress throughout the screening process during an athlete's overall physical literacy.

Finally, it would be expected that many elite level athletes would have mastered this movement due to the amount of time spent performing this or similar exercises in the weight room for their own physical development. Although the screen can be used for anyone, it may offer coaches more information for inexperienced athletes while they are still learning how to control complex movement patterns.



**Figure 1. (on left)**  
Overhead squat (anterior view)



**Figure 2. (on right)**  
Overhead squat (lateral view)



**Figure 3.**  
**(on left)**  
Overhead squat  
(posterior view)



**Figure 4.**  
**(on right)**  
External rotation  
of the feet



**Figure 5.**  
**(on left)**  
Feet flatten



**Figure 6.**  
**(on right)**  
Heels raise



**Figure 7.**  
**(on left)**  
Knee valgus



**Figure 8.**  
**(on right)**  
Knee varus





**Figure 9.**  
(on left)  
Lumbar arching



**Figure 10.**  
(on right)  
Lumbar rounding



**Figure 11.**  
(on left)  
Excessive forward lean



**Figure 12.**  
(on right)  
Arms fall forward



**Figure 13.**  
(on left)  
Elbows flex



**Figure 8.**  
(on right)  
Protruding head

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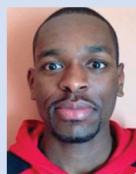
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